Possible rotation-power nature of SGRs and AXPs

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Objective

Following **Belvedere** *et al.(2014), we obtained* B *and* $\dot{E}_{rot}$ *for SGRs/AXPs:*

- *when realistic structure parameters are used:*
  - *Nuclear equation of state* $\rightarrow$ $\epsilon = \epsilon(P)$;
  - *Stability conditions of both static and rotating neutron stars.*
- *when General Relativistic corrections to* B *are introduced;*
- *for Local charge neutrality and Global charge neutrality (Coulomb interactions turned on).*

We show:

- *that 40% of the observed* **SGRs/AXPs** *can be canonical pulsars -* **rotation powered Neutron Stars***;*
- *the range of* **masses** *for which this is possible;*
- *the predicted* **glitches** *for this sources.*

SGRs/AXPs - The Sources

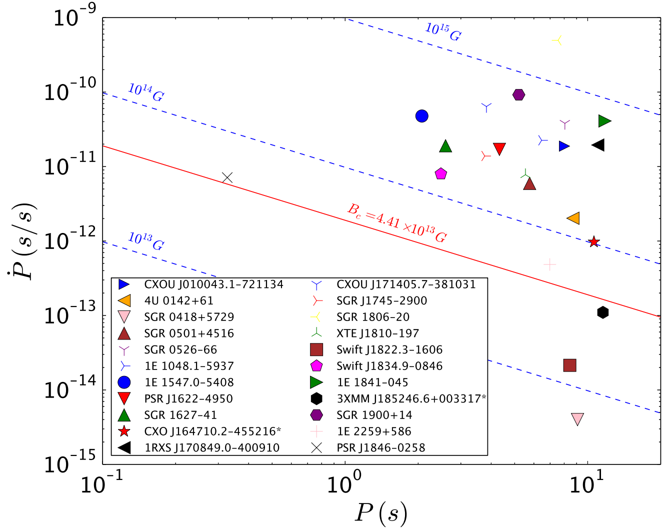
SGRs - Soft Gamma Repearters.
AXPs - Anomalous X-ray Pulsars.

Particular class of pulsars:

Pulsars		
	Ordinary Pulsars	SGRs/AXPs
P	$\approx (10^{-3} - 10)s$	$(2 - 12)s$
$\dot{P}$	$\approx 10^{-15}\ s/s$	$\approx (10^{-10} - 10^{-12})s/s$
L_X	$\approx 10^{30}\ erg/s$	$\approx (10^{34} - 10^{36})erg/s$
t_c	$> 10^6\ yr$	$\approx 10^3\ yr$

Transient Activities	
outbursts	$\sim (10^{41}$–$10^{43})$ erg
giant flares	$\sim (10^{44}$–$10^{47})$ erg

Our sample, $P - \dot{P}$



SGRs/AXPs - What are they?

Widely accepted as **Canonical Neutron Stars**:

- Slowly rotating Neutron Stars - $P \approx (2 - 12)$s:
  - $M = 1.4 M_{\odot}$
  - $R = 10\ km$
  - $I \approx 10^{45} g\ cm^2$
- Large x-ray luminosity - $L_X > \dot{E}_{rot}$.
- Powered by strong magnetic fields - $B > 10^{14}$G.

Pulsar Theory

Observables	
Pulsar Period	P
Age of a Pulsar	$t_c = P/2\dot{P}$
Magnetic Field	$B = \sqrt{\frac{3Ic^3}{8\pi^2 R^6}P\dot{P}}$
Energy Release	$\dot{E}_{rot} = -4\pi^2 I\dot{P}/P^3$

Canonical Neutron Star

$$B_{NS} = 3.2 \times 10^{19}(P\dot{P})^{1/2}\ G$$
$$|\dot{E}_{rot}|_{NS} = 3.9 \times 10^{46}\dot{P}/P^3\ erg/s$$

Algorithm

- **EOS** - Nuclear matter: Relativistic mean field-theory approach, nucleons interact via the exchange of mesons. Three parametrizations: GM1[1], TM1[2], NL3[3];
- **Global Neutrality** - Coulomb interactions are allowed, Einstein-Maxwell-Thomas-Fermi equations [4]
- **Structure** - Slowly Rotating Star: small dapartures from the TOV like solutions: Hartle Procedure[5];
- **Pulsar** - Observed periods and luminosities.

1 G. A. Lalazissis, J. König, and P. Ring, **Phys. Rev. C 55, 540 (1997)**.

2 K. Sumiyoshi, H. Kuwabara, and H. Toki, **Nuclear Physics A 581, 725 (1995)**.

3 N. K. Glendenning and S. A. Moszkowski, **Phys. Rev. Lett. 67, 2414 (1991)**.

4 R. Belvedere, D. Pugliese, J. A. Rueda, R. Ruffini, and S.-S. Xue, **Nucl. Phys. A 883, 1 (2012)**

5 Hartle, J. B., **ApJ 150, 1005 (1967)**.

EOS: Mass-Radius

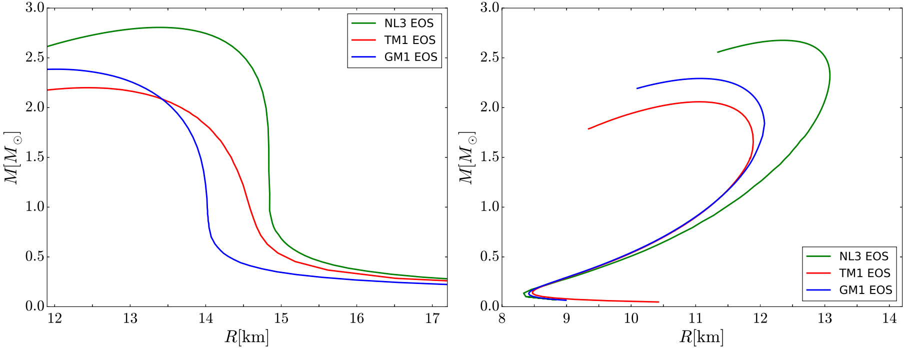


Figure : Mass-Radius relation for the NL3, TM1, and GM1 EOS in the cases of local (left panel) and global (right panel) charge neutrality.

GR Magnetic Field

$$f = -\frac{3}{8}\left(\frac{R}{M_0}\right)^3\left[\ln(N^2) + \frac{2M_0}{R}\left(1+\frac{M_0}{R}\right)\right], \qquad (1)$$

$$N = \sqrt{1-\frac{2M_0}{R}}, \qquad (2)$$

$$B\sin\chi = \frac{N^2}{f}\left(\frac{3c^3}{8\pi^2}\frac{I}{R^6}P\dot{P}\right)^{1/2}. \qquad (3)$$

1 Rezzolla and Ahmedov, **MNRAS 352, 1161 (2004)**.

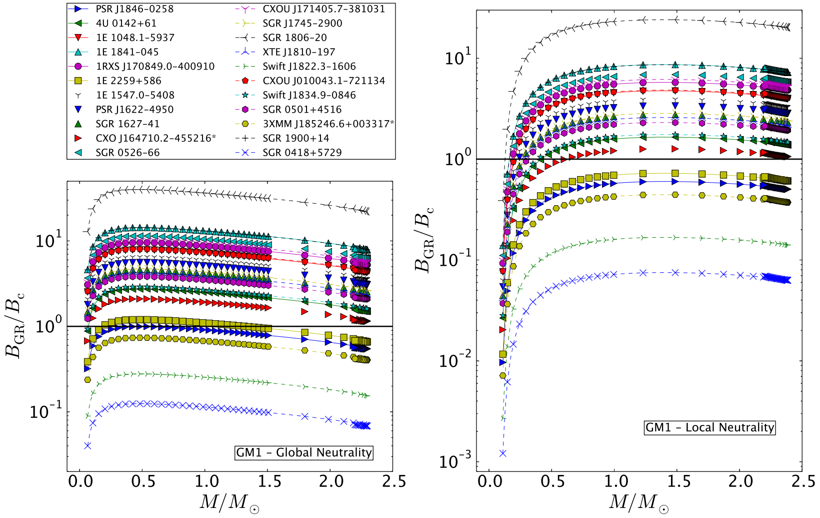


Figure : Magnetic field B_{GR} with a relativistic correction, in units of critical field B_c, as function of the mass (in solar masses) in the cases of global (left panel) and local (right panel) charge neutrality.

Efficiency

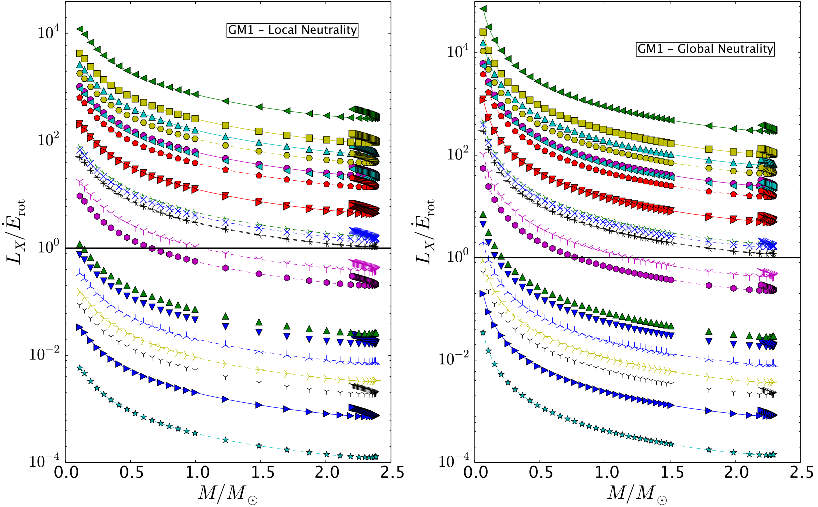


Figure : Ratio between the observed X-ray luminosity L_X and the loss of rotational energy $\dot{E}_{\rm rot}$ versus total mass of the rotating NS, in units of $M_\odot$, for the global neutrality case.

Rotation Powered

- $L_X/\dot{E}_{\rm rot} < 1$: Swift J1834.9–0846, PSR J1846–0258, 1E 1547.0–5408, SGR J1745–2900, XTE J1810–197, PSR J1622–4950, SGR 1627–41, SGR 0501+4516, CXOU 171405.7–381031.
- $L_X/\dot{E}_{\rm rot} \sim 1$: SGR 1900+14, SGR 0418+5729, and Swift J1822.3–1606.
- among these nine sources, we can also find six sources with possible associations with supernova remnants (SNRs): Swift J1834.9–0846 associated with SNR W41, PSR J1846–0258 (with SNR Kes75), 1E 1547.0–5408 with SNR G327.24–0.13, PSR J1622–4950 with SNR G333.9+0.0, SGR 1627–41 with SNR G337.0-0, CXOU J171405.7–381031 with SNR CTB37B

Canonical NS

Source	P (s)	$\dot{P}(\times 10^{-11}$ s/s)	$B_{NS}^{\rm fiducial}(\times 10^{14}$ G)	$L_X(\times 10^{33}$ erg/s)
SGR 0501+4516	5.8	0.59	1.9	0.81
1E 1547.0-5408	2.07	4.77	3.2	1.3
PSR J1622-4950	4.33	1.7	2.7	0.44
SGR 1627-41	2.59	1.9	2.2	3.6
CXOU J171405.7-381031	3.8	6.4	5.0	56
SGR J1745-2900	3.76	1.38	2.3	0.11
XTE J1810-197	5.54	0.77	2.1	0.043
Swift J1834.9-0846	2.48	0.79	1.4	0.0084
PSR J1846-0258	0.33	0.71	0.49	19

- It is interesting to notice that four of the above nine sources, namely 1E 1547.0–5408, SGR J1745–2900, XTE J1810–197, and PSR J1622–4950, are actually the only ones with detected radio emission, as expected from ordinary rotation-powered pulsars.

Predicted Glitches for the RPP SGRs/AXPs

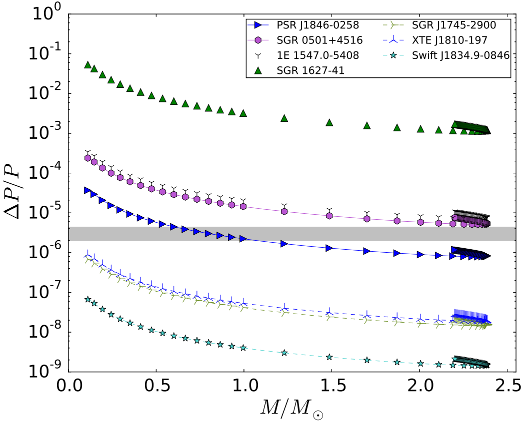


Figure : Inferred fractional change of rotation period during the glitch, $\Delta P/P$, obtained by equating the rotational energy gained during the glitch, $\Delta E_{\rm rot}$, to the energy of the burst. In this example the NS obeys the GM1 EOS and local charge neutrality is adopted. The gray-shaded area corresponds to the value of $|\Delta P|/P$ in the observed glitch of PSR J1846–0258 in June 2006.

Table : Predicted values of $|\Delta P|/P$ assuming rotation-powered NSs - Local Charge Neutrality

Source name	Total isotropic burst energy [erg]	Predicted $|\Delta P|/P$ for $M > 1\,M_{\odot}$
PSR J1846–0258	4.8×10^{41}	$(7.9 \times 10^{-7} - 2.2 \times 10^{-6})$
1E 1547.0–5408	1.1×10^{41}	$(7.2 \times 10^{-6} - 2.0 \times 10^{-5})$
XTE J1810–197	4.0×10^{37}	$(1.9 \times 10^{-8} - 5.3 \times 10^{-8})$
SGR 1627–41	1.0×10^{43}	$(1.1 \times 10^{-3} - 3.2 \times 10^{-3})$
SGR 0501+4516	1.0×10^{40}	$(5.0 \times 10^{-6} - 1.4 \times 10^{-5})$
Swift J1834.9–0846	1.5×10^{37}	$(1.4 \times 10^{-9} - 3.9 \times 10^{-9})$
SGR 1745–2900	6.7×10^{37}	$(1.4 \times 10^{-8} - 4.1 \times 10^{-8})$

Conclusions

- We explored the consequences of a realistic model for neutron stars to the observables of SGRs/AXPs.
- For the chosen models the X-ray luminosity of some sources can be explained via loss of rotational energy.
- $L_X/\dot{E}_{rot}$ is **overestimated** for fiducial parameters.
- B is **overestimated** for fiducial parameters.
- We have explored for the nine sources with $L_X < \dot{E}_{\rm rot}$ the possibility that the energetics of their bursting activity, $E_{\rm burst}$ be explained from the rotational energy gained in an associated glitch, $\Delta E_{\rm rot}$. We thus computed a lower limit to the fractional change of rotation period of the NS caused by the glitch, $|\Delta P|/P$, by requesting $\Delta E_{\rm rot} = E_{\rm burst}$. The fact that exist solutions for $|\Delta P|/P$ reinforces the possible rotation-powered nature for these sources (e.g., the case of PSR J1846–0258).

ACKNOWLEDGMENTS

C A P E S

Obrigado! Grazie!